

AN EVALUATIVE EFFECT OF TEMPERATURE ON THE HUMAN COGNITIVE RESPONSE USING STROOP TEST

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ABSTRACT

The effect of temperature on the human cognitive response was studied using the Stroop test. In the study, 80 participants were subjected to temperatures varying from 5 °C to 40 °C and the Stroop score was measured. It was observed that 32.5% participants showed least Stroop score at 30 °C and 51.25% at 40 °C indicating better and quicker cognitive response at higher temperatures. Analysis using regression studies indicated a negative linear correlation between Stroop score and temperature with multiple R and R square value of 0.998 and 0.997 respectively. These results seem to indicate that participants were investing a greater amount of cognitive effort for a fast completion of the given task when exposed to thermal stress in order to compensate for the increased feeling of discomfort.

KEYWORDS: Thermal Environment, Stroop Effect & Cognitive Response

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INTRODUCTION

The prevalence of elevated temperatures is a common on the shop floor of many manufacturing industries like forging units, heat treatment plants etc. In addition, India's geographical location in the tropics, rising global temperatures, long summer season, lack of ventilation, poorly designed factories, etc. are also the reason for elevated temperatures in small and large manufacturing units.

The effect of environmental factors on job performance were exhaustively studied by kayo⁽¹⁾. In his study, he investigated the effects of job characteristics (physical efforts and job grade), and working conditions (environmental conditions and hazards) on task performance and contextual performance. He found a significant relationship between environmental conditions and task and contextual performance. The effect of poor workplace conditions (physical efforts, environmental conditions, and hazards) was found to result in decreasing employee performance.

It is expected that environmental factors would have an effect on physiological as well as cognitive performance in human beings. Furtado et al.⁽²⁾ Studied the effect of heat stress on physiological effects and task performance and found that simple tasks were less affected by heat stress compared to complex tasks such as tracking, monitoring and multiple tasks.

Though the effects of temperature on physical performance of humans are well studied and documented, in contrast, the effect of temperature on human cognitive abilities is less researched.

The effects of heat stress on cognitive performance studied by few researchers have shown that heat affects cognitive performance differently based on the type of cognitive task^(3,4,5,6). It was observed that mental or

very simple tasks typically show a little decrement in the heat and are frequently enhanced during brief exposures. Whereas, other perceptual motor tasks depicted a pattern of onset of performance decrement with elevated temperatures. In a meta-analysis study by Hancock et al.⁽⁷⁾ a substantial negative effect on performance associated with thermal stressors was observed, with the overall effect size for heat being comparable to that for cold. Cognitive performance was found to be least affected by thermal stressors, whereas both psychomotor and perceptual task performance were degraded to a greater degree. They concluded that heat stressors detrimentally influence perceptual capabilities, followed by motor responses, with cognitive attributes least affected but still subject to decrement. They found that stress forces the individual to allocate attentional resources to appraise and cope with the threat, which reduces the capacity to process task-relevant information.

Effects of hyperthermia during a heat stress test on four cognitive functions (working memory, attention, response speed and processing speed) was studied by Stubblefield et al.⁽⁸⁾. The authors found that though hyperthermia reduced working memory performance and processing speed over time, the response speed and attention were less influenced by high body temperature.

Mazloumi et al.⁽⁹⁾ studied the effect of heat stress on cognitive function among workers in a hot industry. They did not find a correlation between heat stress and reaction time in case of stroop test 1 and 2 which involved neutral and congruent colour recognition. In case of the stroop test 3 which involved incongruent colour recognition, the stroop score was higher after exposure to heat stress. They attributed this result to the simple nature of Stroop tests 1 and 2, which require low level of attention in contrast to Stroop test 3 maybe due to the complexity of Stroop test 3. They concluded that heat stress affects cognitive performance differently depending on the type of cognitive task. In tasks, which require low attention, cognitive performance was less, affected by heat stress, compared to more complex tasks, which require more attention.

Gaoua et al.⁽¹⁰⁾ studied the effect of passive heating on memory task performance and attention based processes. Results indicated that there was impairment in working memory with heat exposure without much effect on the attentional processes.

A study of thermal stress on computer based task performance was studied by Chase et al.⁽¹¹⁾ A congruent dual visual- visual task was selected to study the cognitive responses of participants. Performance decrement with an increase in thermal environment was found on one of the visual tasks, whereas changing the thermal environment did not affect the performance on another visual task.

Due to often contradictory findings in existing literature on the effects of thermal stress on cognitive performance, this study was implemented. It was decided to analyse the effect of heat stress on capability to perform short duration work requiring concentration and good responses.

EXPERIMENTAL DETAILS

Controlled environmental chamber of size 4.26 meters x 2.14 meters x 2.44 meters was constructed using aluminium skins and wiced polyurethane foam panels placed on all sides, floor and roof. Heating and air-conditioning equipment capable of providing temperature ranges between 0°C to 50°C was installed.

Participants: Physically fit persons (pre cleared by a physician) between the age group of 16-58 years were allowed to take the test. Familiarity with English (to be able to understand the app) was a precondition to be selected as a

volunteer.

The participant was asked to enter the controlled environment chamber at the beginning of test. During the mandatory thirty minute acclimatization period, volunteer was made familiar with the equipment and tests that he would be undergoing. Participants were allowed to wear winter protection clothing of choice if required during the test duration.

Participants expressed discomfort during initial trials at temperatures below 5° and above 40° C. Hence it was decided that temperature range for the test was to be restricted between 5° to 40°C.

The temperature in the controlled environment chamber was set initially either at 5° or 10°Celsius. Fifty percent of the cases, after the 5° and 10° tests were completed, the temperature was raised to 20°C then to 30°C and lastly to 40°C. In the remaining fifty percent cases the temperature was raised to 20°C then to 40°C and lastly to 30°C. This helped remove bias and introduce randomness.

Participants were asked to perform the Stroop effect test ⁽¹²⁾ with a set of thirty responses. This test involves incongruent color matching of words. At the end of the test, the software displayed total time taken, number of errors and Net score. The Net score (computed by taking into account the errors) was considered for analysis. Statistical analysis was done using excel software.

RESULTS AND DISCUSSIONS

The Stroop test is commonly used to test the cognitive function and responses.⁽¹³⁾ The Stroop test effect helps measure a person's selective attention capacity and skills, as well as their processing speed ability.

In the present study, participants were allowed to get acclimatized to the test temperature for 30 minutes, after which they were asked to complete the Stroop test. The Stroop scores were noted down at the end of each test. The temperature of measurement was 5 °C, 10 °C, 20 °C, 30 °C and 40°C. The Stroop score was interpreted as a measure of cognitive response with low score indicative of higher cognitive response.

It was found that only about 3 to 4% of participants showed least Stroop scores at 5°C, 10% at 20 °C, 32.5% participants showed least Stroop score at 30 °C and 51.25% at 40 °C. This leads us to the conclusion that participants displayed better cognitive response at temperatures of 30 °C and 40°C. Further analysis was carried out using regression studies of the average Stroop score of the 80 participants versus temperature. Table 1 gives the values of the average Stroop score of 80 participants versus temperature.

Table 1: Average Stroop Score versus Temperature

Temperature in Celsius	Average Stroop Score
5	1.748
10	1.667
20	1.585
30	1.506
40	1.467

A linear relationship between the Stroop score, which is the dependent variable and temperature the independent variable was observed. Figure 1 shows the plot of Stroop scores versus temperature.

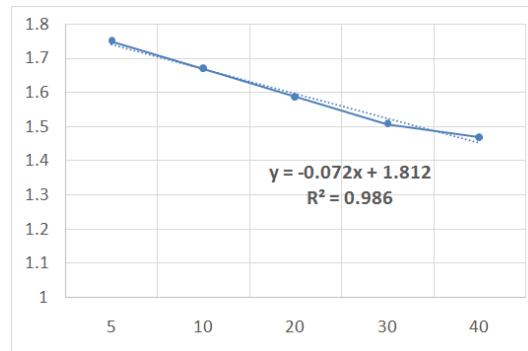


Figure 1: Stroop Score versus Temperature

Regression analysis of the Stroop test gave a multiple R and R square value of 0.998 and 0.997 respectively. The standard error of regression is 0.009 which is close to zero. Table 2 shows Regression analysis values.

Table 2: Regression Analysis

Multiple R	0.98042817
R Square	0.961239397
Adjusted R Square	0.948319196
Standard Error	0.02622498

The value of Multiple R portrays the strong relationship between the two variables. The two variables in this case are Stroop scores (dependent variable) and temperature (independent variable). R Square, which is the coefficient of determination, shows how many points of the data fall on the regression line. The value of R square is equal to 0.961239397, which is close to 1. Therefore, 96.12% of the points in the given data fall on the regression line.

Standard Error of Regression is an estimate of the standard deviation of the error μ . The standard error of the regression is the precision that the regression coefficient is measured. Here the standard error is 0.02622498, which is close to zero. This implies that there is minimal error in the model.

Table 3: Analysis of Variance

	df	SS	MS	F	Significance F
Regression	1	0.051167313	0.051167313	74.39818	0.003277192
Residual	3	0.002063249	0.00068775		
Total	4	0.053230562			

Table 3 shows Analysis of Variance values. The significance, F value was found to be 0.003277192 and F value was 74.39818. Here, Significance F is less than 0.05, and indicates that, overall, the regression model statistically significantly predicts the outcome variable.

Table 4: Correlation Data

Correlation	x	y
Temperature	1	
Stroop score	-0.98042817	1

From the Table 4, it can be seen that the correlation between x and y is -0.9804. This implies that there is a strong negative correlation between temperature and Stroop scores.

CONCLUSIONS

The results showed that around 85 percent of the participants performed better at higher temperatures of 30 to 40 degree Celsius. The study could not be continued beyond 40 degrees because of extreme heat distress experienced by participants. The observed increase in cognitive response from 5 degrees to 40 degrees implies that the participants displayed better cognitive function and higher responsiveness under heat stress.

These results are similar to the results obtained by Grether⁽³⁾ who found highest performance in vigilance at 30 degrees Celsius. Similar results were obtained by Schmit et al.⁽⁶⁾ wherein they observed heat stress consistently resulted in improving both simple and complex cognitive processes when T_{core} (core body temperature) was less than or equal to 38.5°C. They also observed that above this threshold, cognitive performance declined at T_{core} (core body temperature) above 39°C.

As suggested by the above researchers it appears that the mechanism responsible for this cognitive improvement may be complex. It is concluded that this may be attributed to participants investing a greater amount of cognitive effort for a fast completion of the given task when exposed to thermal stress in order to compensate for the increased feeling of discomfort.

Above results suggest that short duration tasks under heat stress may be managed by the operator, however this may not be extrapolated to a longer duration tasks under heat stress. Manufacturers and production engineers must accordingly consider these outcomes while delegating short and long duration tasks at high heat stress levels.

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